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U.S. ARMY FOREIGN SCIENCE AND TECHNOLOGY CENTER

USING AERIAL PHOTOGRAPHY IN DIFFERENT SPECTRUM INTERVALS

TO STUDY VEGETATION AND SOILS

COUNTRY: USSR

TECHNICAL TRANSLATION

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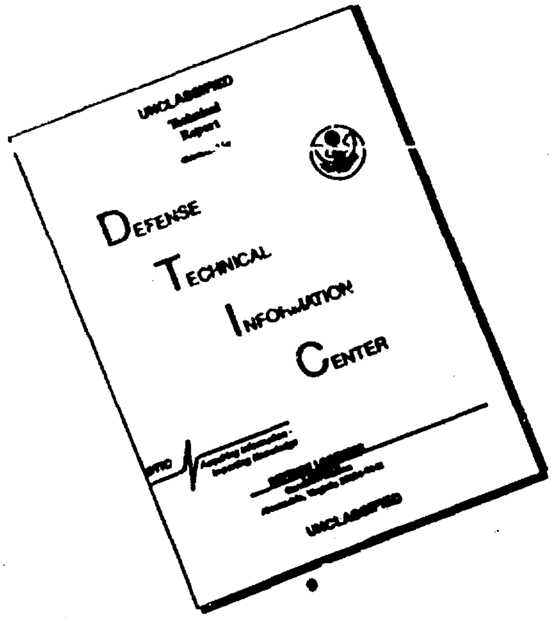

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by

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USING AERIAL PHOTOGRAPHY IN DIFFERENT SPECTRUM INTERVALS TO STUDY VEGETATION AND SOILS

By A. I. Vinogradova

In recent years, in our nation there has been a significant increase in the number of specialists in different areas who make extensive use of aerial photography in their work. Along with broadening the sphere for using aerial methods, we can also clearly note a general move toward greater specificness in the technical and natural conditions of aerial photography. Various departments have ceased to be satisfied with the available finished materials from an aerial photographic survey which have been obtained for different purposes. They are working out their own requirements upon the conditions of aerial photography in terms of the survey scale, the type of film and the light filter, the focal length of the camera and the type of camera, as well as in terms of the season of the photographing, and are conducting the corresponding aerial photographic surveys.

In line with the completion of work on creating the state map of a scale 1:100,000 and with the changeover to a more detailed study of the nation's territory, in all regions a tendency can be observed to enlarge the scale of aerial photographing for making it easier to read the aerial photos and for obtaining the greatest possible amount of information from them.

Thus, enlarging the scale of the aerial photographic survey has been caused by the need to raise the reading properties of the photos and thereby broaden the existing reading properties.

In responding to this need of production, scientific research is being conducted in three basic directions.

1. Increasing the brightness and color contrasts between the images of the landscape elements on the aerial photographs by discovering an effective spectrum interval for the aerial photographing and choosing the corresponding combination of film type and light filter.

2. Increasing the sharpness of the terrain image. The desire for contrast should not eliminate the requirements for the reproduction of a large quantity of terrain situation details on the photos and the possibility of obtaining accurate quantitative characteristics from aerial photos, particularly in line with enlarging the scale of aerial photographing. This involves the work of improving the aerial photographic lenses, increasing the shutter speed, raising the resolution of the photographic emulsions, etc.

The scientific principles for analyzing the geometric and optical conditions of the image of small objects on aerial photographs were put down in our nation in the 1930s by V. A. Faas in the concepts which he proposed and formulated on the detailmetric and photometric scales (Gaveman and Faas, 1940). The work which in essence is analogous to the talented beginnings of V. A. Faas is going on at present.

The sharpness of the contours of the photographic images of objects, along with the reproduction of the smallest details possible, are particularly important requirements made upon aerial photographs which are to be used to read forest vegetation.

3. A particular direction of the scientific research is the desire to create methods of special types of reading: geological, soil, forest, etc. In this regard there is the interesting work of creating a standard terminology to record the characteristics from the aerial photographic images of individual objects: a tone scale, the shape of the objects, the dimension, the density and the character of their distribution over the area, the configuration of the erosion network, etc. A rational standardization for recording the characteristics of the aerial photographic images of objects would facilitate a comparative study of these objects from materials of different surveys. However, proper attention has still not been given to this problem in our special literature.

In the given article, we have attempted to take up only certain problems related to the contents of the first direction of scientific research noted above.

The Nature of the Differences in Optical Properties between Individual Plant Species, Vegetation Communities and Soil Types

Research on the optical properties of plants for the purposes of reading aerial photographs of the ground surface was taken up for the first time in our nation in 1929-1930 at the Leningrad Aerial Survey Institute. The founder of this research was G. A. Tikhov. From 1932 through 1937, the work of G. A. Tikhov was continued by Ye. L. Krinov. Subsequently these same questions were studied by M. V. Savost'yanova. From 1947, under the Presidium of the Kazakh Academy of Sciences, an Astrobotany Sector was set up, where G. A. Tikhov and a group of his students (V. S. Tikhomirov, M. P. [illegible]styakov and others) at present are studying the optical properties of plants in the aim of detecting and proving the presence of organic life on other planets. Information on the spectral reflection from certain types of plants may also be found in foreign literature, for example, in the work by Jensen and Colwell (1949).

The general course of the change in the spectrum-reflective properties over the visible and infrared rays of the spectrum which is characteristic for all green plants is explained as follows in the work of the named authors. The low reflectivity of the plants in the areas of the blue and red rays of the visible spectrum is related to the high absorption of these rays by chlorophyll. A certain increase in reflection in the area of the green rays is caused by the fact that these rays are reflected directly from the chlorophyll granules. The extremely high reflection within the infrared part of the spectrum is ascribed to the complete passage of the infrared rays by the chlorophyll and their reflection from the internal tissues of the leaf (Fig. 1).

One of the reasons for the great difference in the reflectivity in the area of the infrared rays of the spectrum between the coniferous and leafy varieties is felt to be the presence of a spongy parenchyma in the leaves of the latter. This, like foam, very strongly reflects the infrared rays which then emerge through the chloroplasts of the palisade parenchyma and the upper surface of the leaf. In the needles of coniferous varieties, as is known, the spongy mesophyll is absent.

During the stage of the spring and autumn turning of the leaves in line with the varying time of the vegetation phases, great differences are also created in reflection on

the area of the visible rays of the spectrum. With the withering of the leaves, their reflectivity reclines in the area of the infrared rays of the spectrum.

The coniferous varieties ordinarily reflect significantly less light than the leafy varieties over all the designated areas of the spectrum. This, as is supposed, is explained above all by the basic differences between these two groups in terms of density, dimensions, configurations and orientation of the leaves as well as the placement of the branches.

Fig. 1. Spectral curves for the reflection of leafy (1) and coniferous (2) varieties. (According to Krinov, 1947)

Fig. 2. Graph of monthly changes in the reflection energy of coniferous plants in the wavelength area of 560-725 millimicrons. (According to Tikhomirov, 1951). 1 -- spruce of the Canadian sector; 2 -- pine of the Canadian sector; 3 -- spruce of the Canadian sector K-L; 4 -- pine from the Botanical Garden of Kazan' State University; 5 -- Medeo spruce.

In new work on examining the influence of the environment on the spectral-reflective properties of plants, G. A. Tikhov (1949, 1951) has come to the conclusion that for plants in a severe climate, the reflectivity is less than for plants in a mild climate, and that for frost-resistant plants it is also lower than in the drought-resistant ones. In a severe situation, a plant requires a larger amount of solar heat for carrying out its vital functions, and for this reason, the absorption of sunrays is increased and their reflection is reduced. These indices change differently for the seasons of the year for the various plants. The changes in the reflection energy of coniferous and leafy varieties for the various seasons are given in Figs. 2 and 3.

M. P. Ostyakov (1949) established the extremely interesting fact of a change in the brightness coefficients of plants of the same species located under different conditions. Beginning with a wavelength of 541 millimicrons and above, the brightness coefficient of a spruce growing at an altitude of 1,500 meters above sea level was significantly higher than a spruce growing at an elevation of 2,200 meters. The brightness coefficients of spruces located at the same elevation did not evidence such a sharp difference.

In the article by Billings and Morris (1951), results are given from studying the reflectivity of plants in different ecological groups, and these results completely agree with the conclusions given above. The authors point out an increased reflection in the visible area of the spectrum for certain types of subalpine and particularly desert plants, and this is related, in their opinion, to the hairs and waxy coating on the surface of the epidermis, and the increase in reflection in the infrared area of the spectrum (Fig. 4) does not always accompany this. They come to the conclusion that the higher the solar radiation reaching the plants and the drier the habitat conditions, the higher their reflectivity in the visible spectrum, and, judging from the graphs for the spectral reflection properties of these plants appended to the article, the greater the difference here between the individual species. On the aggregate graph (Fig. 5), the average curves are shown for several plants under different habitat conditions. Within the visible spectrum, just as great differences were observed in the reflection between these plants as in the area of infrared rays.

All of the given data are very interesting for the purposes of studying individual plant species and plant communities using aerial photographs. However, the data from

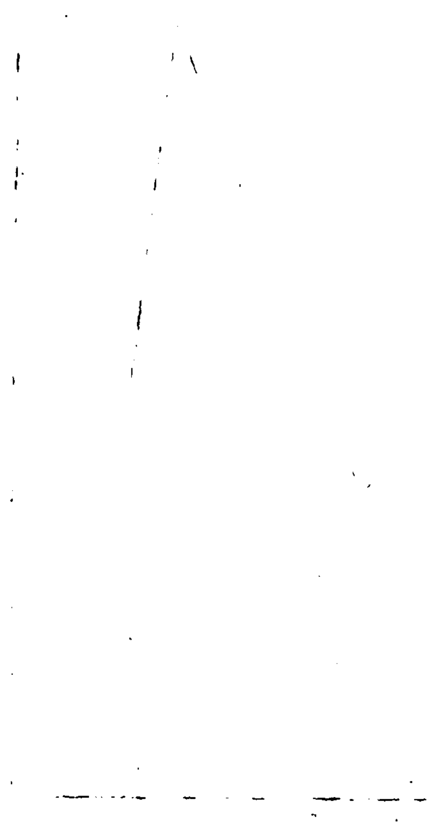

Fig. 3. Graph of monthly changes for the reflection energy of different plants in a wavelength area of 5[illegible]0-725 millimicrons. (According to Tikhomirov, 1951).
1 -- bristlethistle; 2 -- lilac; 3 -- ephedra (green); 4 -- wormwood; 5 -- grass.

spectrophotometry of vegetation and other landscape elements from above, directly from the air, would be of immeasurably greater practical value.

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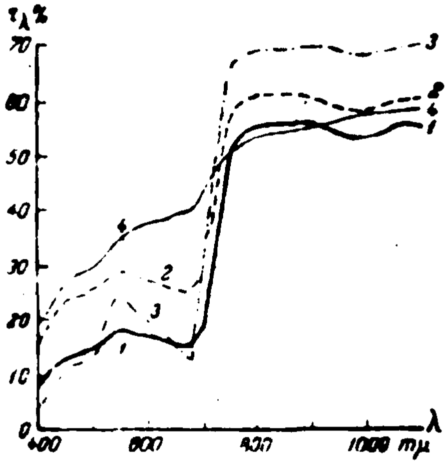

Fig. 4. Spectral curves for the reflection of desert vegetation. (According to Billings and Morris, 1951)
1 -- Atriplex canescens; 2 -- A. lentiformis; 3 -- Prunus andersonii; 4 -- Eurotia lanata.

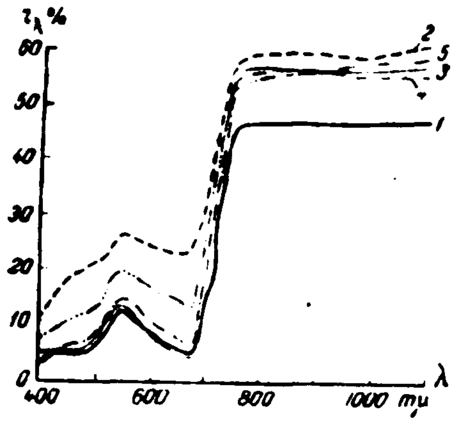

Fig. 5. Reflection spectral curves average for different habitat conditions. (According to Billings and Morris, 1951).
1 -- plains; 2 -- desert;
3 -- north slope pine forest;
4 -- west slope pine forest;
5 -- subalpine vegetation.

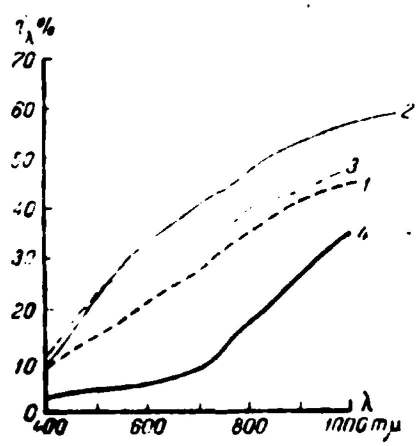

Fig. 6. Reflection spectral curves of soils. (According to Putseyko, 1945).
1 -- plowed soil; 2 -- meadow soil; 3 -- semiswampy; 4 -- swampy.

Certain data on the integral brightness of objects on the earth's surface in the visible part of the spectrum taken from air measurements were obtained by co-workers of the Leningrad Aerial Surveying Institute. In referring to these data, Ye. L. Krinov (1947) stresses one circumstance which is essential for aerial photographing: a rise in the reflectivity of spruce forests within the visible part of the spectrum with their photometry from an airplane, in comparison with data of ground level measurements. This phenomenon is explained by Ye. L. Krinov by the superimposition of predominantly light blue light reflected from the shadowy spaces between the tree crowns on the visible reflection spectrum directly from the crowns. Such an explanation is completely convincing. It makes it possible to propose a considerable role for the patterns of the crown cover precisely within the limits of the visible spectrum, and this, in the first place, significantly simplifies the very complex problem of carrying out spectrophotometry from the air, and, secondly, increases the interest in the aerial photographing of vegetation within the near visible spectrum.

Judging from the indices published in our literature on the spectral reflection of various types of soils [Krinov, 1947; Savost'yanova (Optika v voyennom dele [Optics in Military Affairs], 1945)], between them virtually equal tone contrasts will be obtained with all the combinations of aerial films and light filters (Fig. 6). In all areas of the spectrum, differences in the reflectivity of different soil types are virtually the same. The spectrum area of infrared rays is interesting for studying soil varieties for another reason, namely because of the contrast reproduction even with slight differences in terms of moisture content. Moisture content, in turn, can be one of the criteria in determining the type of soil.

Directly exposed soils are rarely encountered. Ordinarily soils are identified from the type of vegetation confined to them. Because of this, generally the requirements of the geobotanists and soil scientists coincide in terms of the depictive properties of an aerial photograph.

With the present level of development in aerial photography, by knowing the indices for the spectral reflection of various objects on the ground surface, and consequently, being able to obtain their integral brightnesses on the photography area, we still cannot identify them from the data of measuring the densities of the negative layer. Such attempts have not produced results which are of interest for using

aerial photographs. However, this circumstance does not reduce the practical value of materials for studying the optical properties of vegetation, soils and other objects on the earth's surface, in deciding upon the effective area for their aerial phtographing.

Prospective Use for Various Spectral Intervals for Aerial Photographing in Terms of Vegetation and Soils

For correctly choosing the combinations of film and a light filter in the aim of studying vegetation and soils from aerial photographs, it is essential to determine the possible role of different spectral rays in forming the aerial photographic images, considering the optical properties of the objects being photographed.

Ordinarily in aerial photography, it is considered desirable to exclude light from the light blue end of the visible spectrum due to its high dispersion index in the atmosphere, the maximum natural sensitivity of the films to these rays and their low reflection index from the leaf surface. However, shadowy areas are illuminated mainly by the diffuse light of the sky, i.e., by light blue light which they also reflect into the lens of the aerial camera. Because of this, with the complete exclusion of the light blue rays, the blackness of the shadowy areas is increased, and the number of details distinguishable on them is reduced.

Obviously, in photographing from a low altitude or with a slight haze, a better-quality aerial photograph will be obtained with the absence of any filter whatsoever. Along with this, it is essential to point out the advantage of aerial photographic surveys made with high cloudiness, particularly for mountainous regions, since in this instance the details are transferred better over the entire area of the aerial photograph.

At present, in line with the transition to large-scale aerial photographing and, consequently, to the drop in the height of the surveying, the problem of haze has ceased to be a major problem, and the given considerations can be accounted for in practical work, particularly in an aerial photographic survey of forests.

The orange-red light theoretically should be excluded in making aerial photographs of vegetation. Ryker (1933) notes a reduction in the quantity of details depicted in the aerial photos in those instances when the orange-red

light was not excluded. He explains this chiefly by the blinding burst caused by the mirroring of the sun's disc from the leaves on the crown covers facing the sun, and in addition, by the reflection of these rays upwards from the earth's surface and the lower story through the trees. In both instances, according to his statement, the light reaching the camera is rich in orange-red rays. On this basis, Ryker makes the following conclusion: "One can take as axiomatic the circumstance that in using the super pan aerial film for photographing tree vegetation, any light filter which passes orange and red radiation is useless."

The infrared light, because of its great reflection by green plants and low dispersion by atmospheric haze, is extremely interesting for the aerial photographing of vegetation. However, there is the considerable circumstance that within the infrared portion of the spectrum, the leafy varieties reflect much more light than the coniferous ones, and with an optimum exposure a majority of the leafy trees ordinarily are overexposed while a significant portion of the coniferous and all the darkened areas are underexposed with a corresponding loss of detail in the aerial photographic imagery of the forest canopy.

The green rays are less dispersed in the atmosphere than the light blue ones and cause a smaller glare than the orange-red, but most importantly, in aerial photography of vegetation they leave a narrower series of brightnesses between light and shadow than with aerial photographic surveying within the infrared rays of the spectrum. As we have seen above, the spectral reflection curves of leaves from green plants show a difference in the reflection of green rays which is equal and sometimes greater than the limit of the contrast sensitivity of modern emulsions which is considered as equal to 2 percent.

The differences in the structure of the tree crowns and in the structure of the canopy have a considerable influence on the brightness contrasts between the tree vegetation within the visible portion of the spectrum (specifically towards their increase in comparison with the laboratory data). At the same time, the reflection of green rays by the vegetation is sufficiently high and does not require an excessively long exposure.

Consequently, in the area of the green rays of the spectrum, there are all the prerequisites for the good reproduction of details from the structure of the vegetation

cover with a simultaneous contrasting of its aerial photographic image. This is very important for aerial photography.

With aerial photography within the infrared spectrum, in gaining in tone, we lose in the amount of details obtained on an aerial photograph.

The Character of the Vegetation and Soil Image on Black-and-White and Color Aerial Photographs

The character of the vegetation image on the panchromatic aerial photographs in making surveys with different light filters is well known from our daily practices. The information given in foreign literature on this question does not produce anything new. At present, we should note the rather numerous but still little-known works devoted to the results of reading the infrachromatic aerial photographs.

In our nation, aerial photography on infrachromatic film began to be examined in the 1930s at the Leningrad Aerial Surveying Institute It turned out that the basic merit of aerial photography on infrared film is the clarity of depicting objects which are great distances away. Because of this, in long-distance shots, the horizon line ordinarily is clearly distinguishable, particularly in shooting away from the sun.

On the infrachromatic aerial photographs, water is ordinarily depicted in a black tone, and for this reason the water erosion lines are clearly traceable even when located in the background. Shadows are very dense, and the details of an object's structure within the shadowy areas cannot be examined.

In evaluating the merits of materials from the infrachromatic aerial photography in terms of the possibility of identifying vegetation and soils, it must be considered that the infrachromatic film is highly sensitive to light blue, red and infrared rays of the spectrum, with a low sensitivity to the green rays, and for this reason, it does not make it possible to obtain a clear image of details from green vegetation. With large-scale aerial photography, it should also be kept in mind that the camera focus is designed for aerial photography within the limits of the visible spectrum and may produce a certain blurring with infrared photography.

In aerial photographs obtained in making a survey with infrachromatic aerial film in combination with a red

light filter, the green grass and leafy trees are depicted in a very light tone, while a larger portion of the coniferous varieties is dark with a corresponding loss of detail. Dry grass, dead leaves, the forest floor and exposed areas of ground also are dark.

Individual bushes, in merging with the general background of the grass, frequently are not visible at all. Due to the dark tone of the forest floor, and particularly shadowy areas, even in areas which are not solidly planted, it is difficult to determine the base of the trees and consequently to measure their height. Because of the great contrasts between light and shadow, it is sometimes difficult to determine the diameter of the crowns.

In areas where the soil is exposed, the degree of its wetness can be judged from the tone of the aerial photograph. However, it must be kept in mind that waterlogged areas covered with a lush green grass show up in a very light tone and can be much lighter than the surrounding areas with dried grass.

With aerial photography using infrachromatic film and a yellow light filter, the contrast of the image is significantly less than in photographing with a red light filter, and along with the leafy trees, from the degrees of the tone it is possible to establish certain species of conifers (Spurr and Brown, 1946). The possibility of determining the dimensions of the trees from such aerial photographs is somewhat broadened.

Also good for studying the vegetation is the green portion of the spectrum which is best met by the spectral sensitivity curve of the orthochromatic aerial films which have a maximum sensitivity precisely for green rays. The area of the green rays can be isolated also with a combination of a panchromatic aerial film with a green light filter, but in this instance the sensitivity to green rays drops.

At present there is not yet sufficient material for final conclusions on the aerial photographing of vegetation on highly sensitive orthochromatic aerial films. According to the available materials of experimental aerial photography on a scale of 1:10,000 made by the Aerial Methods Laboratory of the USSR Academy of Sciences, it is possible to make only a tentative conclusion in favor of the orthochromatic aerial films in comparison with the panchromatic in identifying tree varieties. In Fig. 7, one can see a definite difference

in the general pattern of the aerial photograph of the same area of forest taken at an interval of not more than 15 minutes with the orthochrome type of aerial film with a yellow light filter and the panchrome film with an orange light filter. In the first instance, the ground surface can be seen better through the canopy of the forest, and more tree varieties can be identified from the difference in tone, and the illuminated and shadowy parts of the crowns as well as the shadows cast by the crowns can be seen more clearly.

In terms of the choice of the scale of aerial photography in photographing forest areas on one or another aerial film, the following considerations should be made. The tone value as an identification feature is increased as the scale drops, and consequently, the role of aerial photography on the infrachromatic films increases, particularly for establishing the types of forest. With an increase in the aerial photography scale, the question arises of the possibility of identifying details in the structure of the forest canopy and obtaining quantitative characteristics from the aerial photos. In the given instance, as many authors assert, the panchromatic aerial films with a green light filter give better results than the infrachromatic ones.

With aerial photography on a scale of 1:10,000, the negative role of red light and the positive role of blue light come more into force. This explains the better results of reading forests obtained in using the panchromatic aerial film with a green light filter in comparison with the yellow. With this combination of film and light filter on aerial photographs with a scale of 1·10,000, individual branches and the nature of the tops of the trees can be examined, and this cannot be done with aerial photographs on a scale of 1:15,000.

The nature of the vegetation image on the aerial photographs, as is known, also changes depending upon the season of photographing.

The autumn and spring vegetation is reproduced with the tone contrasts of their image on panchromatic aerial film which are sufficient to recognize the individual species and plant communities. In the summer season, it is sometimes effective to use infrachromatic aerial film for studying vegetation.

For a detailed examination, it is very useful to have color aerial photography, since the number of colors dis-

Fig. 7. Aerial photographs with a scale of 1:10,000 made of the same forest section. A -- on an orthochrome type film: B -- on a panchrome type film. 1 -- in the first story cedar is predominant with a small admixture of birch and pine (100 years old), in the second story -- birch with an admixture of pine (20 years old): 2 -- a predominance of cedar with a slight admixture of birch and pine: 3 -- predominance of cedar and birch with a slight admixture of pine. Data of ground evaluation of A. M. Berezin.

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tinguishable on a color aerial film is much greater than the number of gray tones distinguishable on a black-and-white one.

Color spectrum-interval aerial photography under the conditions of a desert landscape has no advantages in comparison with black and white. Possibly, this has happened because the photographing was made on a double-layer film with layers sensitized for the infrared and red rays of the spectrum, and the choice of these layers was ineffective for the desert landscapes. At the same time, it is known that the aerial photographing of green landscapes on the same double-layered film gives very interesting results for studying vegetation. This is quite understandable if we consider the spectral-reflective properties of green plants.

Color spectrum-interval films have also been recommended by V. Ya. Mikhaylov (1952) for surveying geological formations and swampy regions. Here the image is in unnatural colors.

Judging from individual statements, experiments on spectral-interval aerial photography on colored two-layered film are also being conducted in the US, but in literature there is no actual information on the merits of such aerial photos.

Specialists in forest identification feel it is useful to have colored photographing on a three-layered film for their purposes. On the colored aerial photographs, there is good visibility of the ground surface through the forest canopy. This, obviously, is explained by the color contrast which arises between the image of the crowns which cast shadows and the earth's surface, since they are all reproduced by different colors.

Research on the merits of color aerial photography is a very urgent problem for the purposes of studying vegetation. Due to the achievements of Soviet scientists, the time is not far off when color aerial photography will be available for broad practical use.

Color aerial photographing abroad is not widely found and is still in the experimentation stage.

The use of color aerial photography in production work is limited by the great expenditures on developing the color aerial photos. Along with the high cost, the restricted

use of color surveying is also explained by the small range of possible exposures.

On the effective use of color aerial photographs in studying vegetation and soils, there are contradictory statements on only a general nature in foreign literature. Certain authors point to their great usefulness, while others refer to their still imperfect quality, as a consequence of which they supposedly have no advantages in comparison with good-quality black-and-white aerial photos.

Of great interest are the attempts to identify materials from color aerial photography, and these experiments are an attempt to use its entire visible spectrum of reflection for each object. For this purpose, a positive print is made on a transparent film. As is known, film printing provides a higher quality of image. On a light table they examine along the route the stereoscopic pairs of color positive transparencies through a set of light filters: yellow, green, red and others, each of which may be optimum for studying one or another object, thus creating the greatest contrast of this object against the background.

In the US, the elaboration of a method to read color aerial photographs is being carried out in the following directions: 1) a study is being made on the nature of the color change of objects under the effect of the atmosphere; 2) they are studying the nature of color blindness which occurs in the human eye in examining very small color objects (Middleton, 1950).

In the aim of reducing material expenditures, the American researchers recommend that on the color film shots be made selectively within the area of a black-and-white survey. A comparison of the colored aerial photographs with the black-and-white ones of the same area will make it possible to extend the results of the reading to the entire filmed area.

In the literature we did not find any data on research on the possibilities of stereophotogrammetric processing of color aerial photographs.

Certain Results on Experimental Aerial Photography of Different Regions with Various Combinations of Aerial Film and a Light Filter

In 1946, Spurr and Brown conducted experimental aerial photography of forests in the eastern states of North America

on a scale of 1:12,000 and 1:20,000. Their task was to use the photographs to separate areas of leafy forests from the conifers, and to work out the features for identifying them. They tested panchromatic and infrachromatic aerial film with different light filters and two types of color aerial film.

During the aerial photographing the grass was green and gave a light tone to the image of the earth's surface both on the panchromatic and on the infrachromatic aerial films. This made it easier to see the grass through the forest canopy.

The authors came to the conclusion that infrachromatic aerial photography with a yellow light filter, in comparison with the panchromatic and color aerial photography, makes it possible to better separate the tree varieties by means of the tonal contrasts, since the differences in the tone are greater in the area of the infrared rays than in the visible spectrum.

With panchromatic aerial photography, regardless of the light filter used, these tonal contrasts could not serve as a reliable criterion for identifying the varieties. Solid differences between the coniferous, leafy and mixed types of forest could be found only in studying the structure of the tree canopy along with the tone. Here it turned out that the panchromatic aerial films reproduced the details better and it is easier to determine the density of the planted area.

The color aerial films could not provide either a faithful reproduction of details or satisfactory color contrasts between the types of forest, and for this reason were not recommended for production aerial photography.

With the same purpose and virtually in the same areas, Jensen and Colwell in 1947 conducted an experimental survey (on a scale of 1:20,000 and 1:15,000) for the California forests (Jensen and Colwell, 1949). However, different results were obtained. On the northern California coast, not one of the tested combinations of various types of film and light filters -- panchrome and infrachrome -- provided tonal contrasts which were sufficient to distinguish between the commercial types of coniferous and leafy trees. The commercial conifers were represented basically by redwood which with all the combinations of aerial film and light filter was depicted in the same tone as the leafy varieties accompanying it.

Curious results were obtained with the aerial photography of the same region on different scales and with different combinations of aerial films and light filter.

Jensen and Colwell photographed the pine forests in the California interior on the same scale (1:20,000 and 1:5,000). Here the aerial survey was made when the grass was yellow and this created a dark tone on the infrachromatic aerial photos and a relatively light one on the panchromatic.

The results of the reading came down to the following. With aerial photographing on the infrachromatic film with a yellow light filter, the leafy trees were somewhat lighter than the coniferous, while on the panchromatic aerial photos, certain leafy varieties looked even darker than the identified coniferous varieties. Regardless of a loss of detail in the infrachromatic aerial photos, they were recognized as more suitable for establishing the leafy varieties from the conifers.

Ryker who photographed the same forest in 1933 on a larger scale -- 1:9,600 -- and who tested films of the panchrome and infrachrome type, came to another conclusion. The tree varieties, according to his observations, are better distinguished with aerial photography on the panchromatic film with a green light filter, i.e., on a spectrum interval of 460-620 millimicrons. Along with the tone, he also used the shape of the crowns in identifying the trees (Ryker, 1933).

Jensen and Colwell feel this conclusion of their predecessor is completely valid for large-scale aerial photography, and is not contradictory to their conclusion.

From Soviet experience on the aerial photographing of forests in different spectrum intervals, there are the widely known results of the work done by the Aerial Methods Laboratory of the USSR Academy of Sciences conducted in the Moscow region on a scale of 1:10,000 (Pronin, 1949). The panchromatic aerial photos made it possible to determine the specific composition only in terms of geometric features. On the infrachromatic aerial photos obtained in surveying with a red light filter, areas of coniferous and leafy forests could be clearly distinguished, and in the mixed plantings the percentage of the admixture was determined by counting the crowns. Areas of pine and spruce forests were also identified from the tone. In the leafy forests, individual varieties were not identified. A comparative evaluation of the aerial photographs in terms of the possibility of measuring the tree height and the crown diameters was not made. During

the summer aerial photography on orthochromatic film, perceivable tone contrasts were created between the areas of coniferous and leafy forests. Obviously, on the autumn and spring orthochromatic aerial shots designed for the different vegetation phases of the vegetation being photographed, the tonal differences will be significantly higher between the image of the individual varieties.

This brief review of the work leads us to the conclusion that the choice of the aerial photography conditions for solving one or another problem related to studying vegetation is very complex and cannot always be the same in all instances.

The listed works contain some information on the possibility of studying grass associations and soils from the tone of their aerial photographic image. There are no published results on special experiments conducted with the aim of solving this problem. It is only known that significant tone contrasts are obtained on the infrachromatic aerial photos between areas of dried grass which are dark and areas of fresh grass which are very light. Here the vegetatior is an indicator of soil wetness.

In American journals, the infrachromatic aerial film has been widely advertised as an effective means for detecting the percentage of wheat rust. It is asserted that the more heavily the area is infested, the darker its tone will be on the aerial photograph, and it is possible to detect several degrees of tone change. The aerial photographs appended to the article appear convincing (Photogrammetric Engineering, Vol 19, p 471).

On areas where the ground is exposed, as was stated above, small changes in wetness produce marked changes in the tone. The contours created by the moisture can make it easier to focus the stereoscopes in measuring within pastures.

Judging from the spectral reflection curves for the various types of grassy vegetation, particularly xerophyte, it would be interesting to set up experiments for its aerial photography within the green portion of the spectrum, and precisely on orthochromatic aerial films.

The results of the experiments described above on the aerial photography of different regions with different combinations of film with light filters show that the choice of the film and light filter combination, in combination

with the choice of the surveying season, is a local problem which depends both upon the nature of the vegetation in the given region as well as upon the research goals. Obviously no general formulas can be given, since different aerial photography conditions are required for solving the same problems in different areas.

In describing the existing opportunities for studying vegetation and soils by using aerial photography in different spectral intervals, we should point out the advances made in the techniques of aerial photography. Research on the nature of differences in the optical properties between objects on the earth's surface in the aim of determining the spectrum interval effective for their aerial photography was begun at the Leningrad Aerial Surveying Institute in 1929-1930.

V. A. Faas provided a scientific basis for the necessity of a differentiated approach to choosing the technical conditions of aerial photography within different landscape zones (Sol'skiy, Faas and Sharonov, 1939). G. A. Tikhov, V. V. Sharonov and Ye. L. Krinov laid down the beginnings for the elaboration of technical conditions in aerial photography in terms of the problems of studying individual landscape elements. In 1935, V. V. Sharonov established the effectiveness of vegetation aerial photography in the infrared spectrum.

However, at the same time, the conclusions obtained could not be applied in practice because of the absence of the required types of aerial films with sufficiently high sensitivity indices and the corresponding aerial photographic equipment. There could be no question of any color aerial photography. The present level in the technical development of aerial photography provides broad opportunities for the practical achievement of such research and, with favorable results, for subsequent extensive introduction into the practice of geological and geographic research.

Color aerial photography on two and three-layered films from low altitudes at present is no problem. Aerial photography in infrared rays has become an ordinary process. There has been a significant increase in the sensitivity and resolution of the previously existing types of panchromatic and orthochromatic aerial films. The modern aerial photography cameras provide broad opportunities for choosing lenses with differing focal lengths, highly orthoscopic lenses and lenses with high resolving power indices.

In line with this, we should remember the forgotten merits of the orthochromatic aerial films particularly for studying our forests.

At one time, V. A. Faas pointed out the advisability of using the orthochromatic material for large-scale planned aerial surveys and the inadvisability of enlargement by aerial photography in the long-wave part of the spectrum (Sol'skiy et al., 1939). The latter was used with small-scale aerial surveying as a measure to combat haze, and for this reason the aerial photographing was done only on panchromatic aerial films, while the orthochromatic aerial films were taken out of mass production. At present, the merits of the orthochromatic aerial film are again coming into play in line with the changeover to large-scale aerial photography and due to the achievements of our photochemical industry.

For further improving the methods of studying vegetation and soils using aerial photography in the various spectrum intervals and for the practical use of these methods in geobotanical, forest management, soil and other work, the following is essential.

1. A study and generalization of the existing experience in the aerial photography of different regions of our land under different natural and technical surveying conditions.

2. Conducting special work to discover these conditions in terms of the different landscape situation and in terms of the various tasks to be solved by using aerial methods.

3. Research on the nature of the reproduction of geometric properties of the studied objects in aerial photography on different types of aerial film, along with an evaluation of the nature of the reproduction of their optical properties.

4. Research on the effectiveness of aerial photography using highly sensitive orthochromatic as well as the two and three-layered color aerial films for forest, meadow, swamp and other vegetation.

5. Determining the advisability of simultaneous aerial photography with two or more cameras using different combinations of film and a light filter, in areas which are inaccessible for ground work, in the aim of reducing the amount of field identification.

6. A study of the spectral reflective properties of objects on the earth's surface and above all the indices for the brightness contrast between the elements of the plant and soil cover for different zones of the spectrum under conditions which are closest to the conditions of their aerial photographing.

7. Discovering the features for reading the elements of the plant and soil cover from the materials of spectral-interzonal and infrachromatic aerial photographs. For these types of aerial films, ordinarily different tone ratios are obtained for the images of the objects than with aerial photography in the visible spectrum, and objects may be depicted which are hard to distinguish or completely invisible on the spot for the naked eye.

8. A further elaboration of simplified methods for obtaining the quantitative characteristics of objects from aerial photographs and the designing of corresponding instruments which are simple to use, convenient and accessible for broad use by specialists in the geological and geographical areas.

9. With the present level of technical knowledge for a further improvement in aerial research methods for vegetation and soils, it is essential to have close collaboration of creative thought in the area of aerial photographic surveying and above all in aerial photography and photogrammetry, on the one hand, and in the area of forest management, soil science and botany, on the other. For discovering the conditions whereby the research objects become readable from aerial photographs, the forestry workers, soil scientists and botanists must master a certain amount of knowledge in the area of aerial photography and participate actively in the practical work of specialists in this area.

10. At present, we can still note a significant gap between the scientific achievements in the area of the development of aerial methods and their introduction into the practical work of forestry workers, botanists, soil scientists and other specialists. The creation of the corresponding teaching aids and methodological manuals will be one measure on the way to eliminating this gap. In these aids and manuals, the necessary information from the area of photogrammetry, aerial photography and photometry should be given in a language accessible for the nonspecialist. Along with this, it is essential to describe the ways for approaching research by using aerial photos of individual landscape

elements and individual types of landscape complexes on the basis of analyzing the already accumulated experience.

The solution to the listed problems will help in making fuller use of both the already existing aerial photographic survey materials as well as the recent achievements in the area of aerial photography and other related sciences in conducting the most diverse research.

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13. ABSTRACT

In recent years, in our nation there has a significant increase in the number of specialists in different areas who make extensive use of aerial photography in their work. Along with broadening the sphere for using aerial methods, we can also clearly note a general move toward greater specificness in the technical and natural conditions of aerial photography. Various departments have ceased to be satisfied with the available finished materials from an aerial photographic survey which have been obtained for different purposes. They are working our their own requirements upon the conditions of aerrial photography in terms of the survey scale, the type of film and the light filter, the focal length of the camera and the type of camera, as well as in terms of the season of the photographing, and are conducting the corresponding aerial photographic surveys.

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